Vertical Variability and Lateral Distribution of Late Wisconsinan Sediments Parallel to the Axis of the Buried Valley of Mud Brook North of Akron, Summit County, Ohio

John P. Szabo[1], Christine G. Huth-Pyscher and Vaughn A. Kushner, Department of Geology & Environmental Science, University of Akron, Akron, OH USA

Abstract. The buried valley of Mud Brook in northern Summit County, OH, contains sediments associated with the late Wisconsinan glaciation. The vertical variability and lateral distribution of these sediments can be ascertained from information derived from logs from highway borings and water wells along a 15-km north-south transect parallel to the axis of the buried valley. Textural, carbonate, clay mineral, and lithologic analyses of samples from roadcuts, geological borings, and some highway department borings provide additional information to assign lithofacies units to specific glaciations. Cross sections show that nearly similar depositional environments existed before each late Wisconsinan glacial advance. The proglacial sediments consist of outwash and lacustrine deposits overridden by ice that deposited an overlying till. Sediments associated with the Lavery and Hiram advances overlie a Kent-aged kame plateau within the Summit County Morainic Complex at the southern end of the study area. Farther north meltwater accumulated and drowned ground moraine to form post-glacial lakes that were eventually drained as the drainage network of Mud Brook became better integrated.

Date of publication: January 2013 **OHIO J SCI 111 (2-5): 18-27**

INTRODUCTION

The deposits in the buried valleys of the glaciated northern Allegheny Plateaus may contain a record of several glacial advances during the Pleistocene epoch. Several of these valleys such as that of the lower Cuyahoga River in northern Ohio are being exhumed by modern rivers; tributaries of these rivers dissect the valley fill exposing sediments that represent processes associated with glaciation (Szabo 1987, 2006a). Other buried valleys remain completely filled and may be poorly drained by low-gradient, sluggish streams flowing across old lakebeds and through wetlands (Ohio Drilling Co. 1971). Mud Brook in northern Summit County, OH (Fig. 1), is an example of the latter where the glacial stratigraphy can only be determined by the use of subsurface data.

The buried valley beneath Mud Brook is located five km east of that of the lower Cuyahoga Valley. The local glacial stratigraphy and proximity of these two large bedrock valleys suggest that master streams may not have occupied both valleys at the same time (Szabo, 2006a). The occurrence of late Wisconsinan tills on interfluves of streams dissecting the valley fill of the Cuyahoga River valley may imply that it was completely filled prior to the late Wisconsinan glaciation. Kushner (2006) has inferred that the valley of Mud Brook may have been incised to bedrock prior to late Wisconsinan advance based on the presence of deeply weathered Orangeville shale found in borings into the valley bottom. Additionally, farther to the south Wilson (1991) found thick sequences of late Wisconsinan sediments. The purpose of this study is to examine the vertical variability and distribution of late Wisconsinan sediments in a north-south direction parallel to the axis of the buried valley of Mud Brook.

The bedrock geology and glacial geology of the study area are variable. The buried valley of Mud Brook (Fig. 2) begins near State Route 82 in northern Summit County (Smith and White 1953, Schmidt 1979) where it is incised into siltstones and shales of the Mississippian Cuyahoga Formation. The bedrock valley floor descends at the rate of six m/km and is eroded into Devonian shales in the southwest corner of the study area (Fig. 2). Sandstones and conglomerates of the Pennsylvanian Sharon Formation underlie the adjacent uplands (Fig. 3). A seismic investigation (Gardner 1981) of the buried valley south of Steeles Corners Road (Fig. 2) suggests that the valley may be deeper than indicated on the generalized map (Fig. 2). A resistivity survey centered on the area bounded by the 700-foot bedrock contour north of Steeles Corners Road (Fig. 2) determined that the fill of the buried valley was dominated by clay with layers or lenses of silt, sand, and sand and gravel (Olver 1981).

The area was affected by several Pleistocene glaciations. Illinoian deltaic and lacustrine sediments up to 40 m thick and tills are found

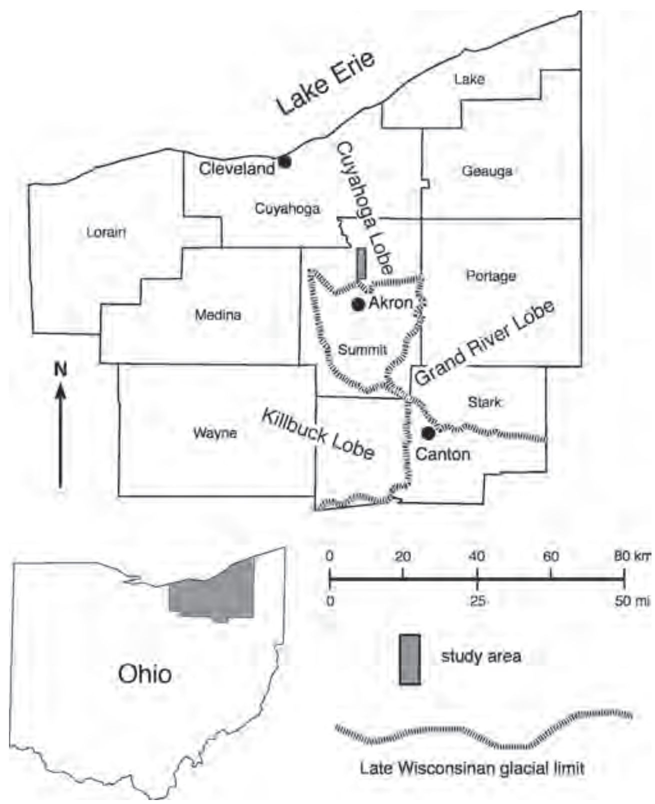


Figure 1. Location of study area near the former southern margin of the Late Wisconsinan Cuyahoga Lobe north of Akron, Ohio. Akron and much of southern Summit County are in a Wisconsinan interlobate area and were last covered by ice during the Illinoian glaciation.

[1]Address correspondence to John P. Szabo, Department of Geology & Environmental Science, University of Akron, Akron, OH 44325 USA, Email: jpszabo@uakron.edu

in valleys of tributaries to the Cuyahoga Valley to the west (Ryan 1980, Szabo and Ryan 1980, Szabo 1987) and are associated with the ice advances that deposited the Millbrook and Northampton tills (Table 1). The late Wisconsinan Kent, Lavery, and Hiram tills (Table 1) are well represented in the study area (Ryan 1980, Wilson 1991, Kushner 2006) but may be absent in parts of the adjacent Cuyahoga Valley.

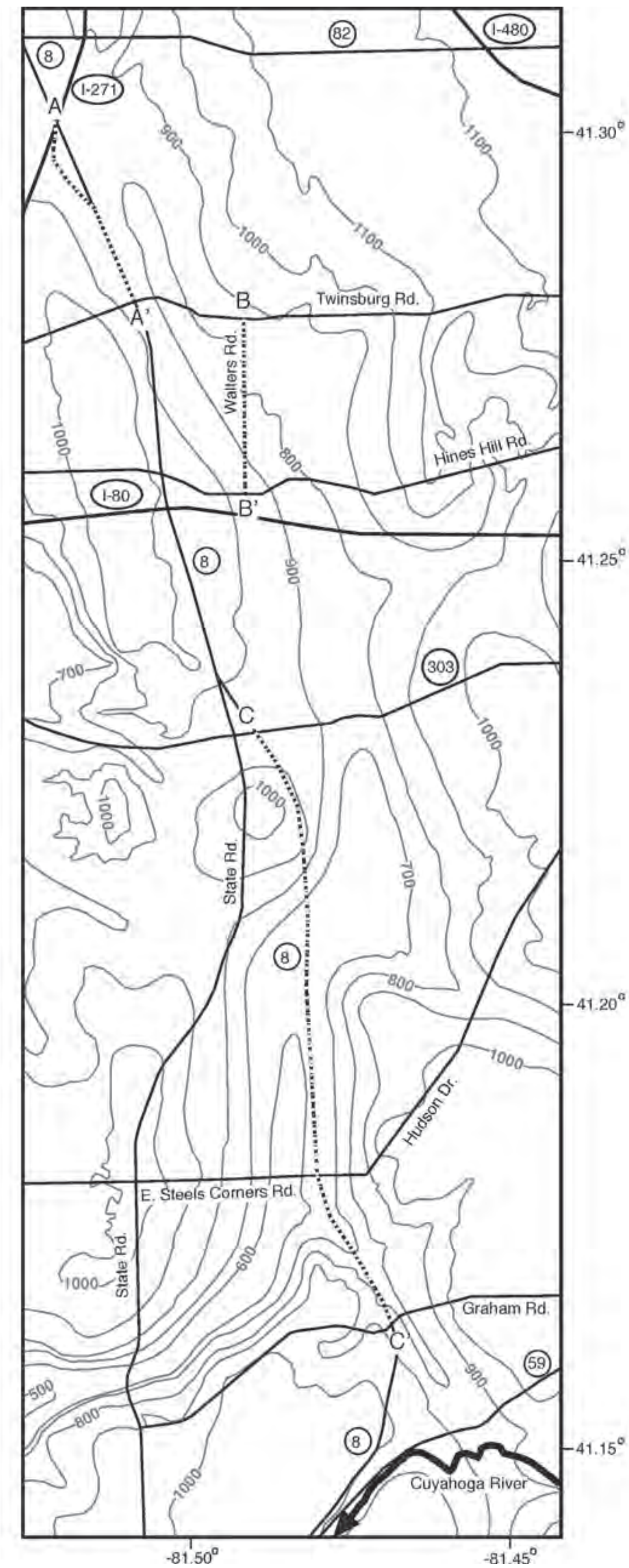
The topography of the lowland over the buried valley consists of gently rolling knolls of till surrounded by nearly flat areas occupied by wetlands and former lakebeds. The topography near Steeles Corners and Graham roads in the southern part of the study area (Fig. 3) consists of moraine and ice-contact deposits of the Summit County Morainic Complex (White 1982, 1984). The morainic complex is a superposed moraine having its bulk composed of Illinoian Northampton Till with successive layers of Lavery and Hiram tills draped over it (Ryan 1980). A large lakebed extends northward from the Complex to elements of the Defiance Moraine to the west (Pavey and others, 1999). Mud Brook originates in this lakebed and flows southward through wetlands within the morainic complex before turning westward (Fig. 3) to eventually join the Cuyahoga River.

Allahiari (1983) performed a morphometric analysis of the Mud Brook basin and showed that there were differences between tributaries of Mud Brook that drain the area over the buried valley and those that drained the valley fill of the Cuyahoga Valley southwest of the study area. Downcutting by upper Mud Brook is limited by a sandstone knickpoint near the intersection of State

Table 1

Tentative correlations of lithologic units in north-central and northeastern Ohio

Time	Killbuck Lobe	Cuyahoga Lobe	Grand River Lobe
Late Wisconsinan			Ashtabula Till
	Hiram Till	Hiran Till	Hiram Till
	Hayesville Till	Lavery Till	Lavery Till
	Navarre Till	Kent Till	Kent Till
Middle Wisconsinan through Sangamonian			
Illinioan	Northampton Till	Northampton Till	not found
	Millbrook Till	Mogadore Till	Titusville Till
			Keefus Till
PreIllinoian		Mapledale Till?	Mapledale Till



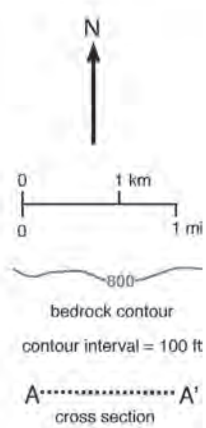


Figure 2. Top-of-rock map showing contours on the bedrock surface and location of cross sections discussed in this paper.

Route 8 and Graham Road in the southwestern part of the study area (Fig. 2). Upstream of the knickpoint the tributary basins to Mud Brook have long first-order streams, low mean channel slopes, and low basin reliefs, whereas those downstream of the knickpoint have high mean channel slopes, high basin reliefs, and large stream frequencies and drainage densities (Allahiari 1983). These tributaries are closer to the Cuyahoga River, which is the base level for lower Mud Brook.

The deep dissection of the lower Cuyahoga valley and its tributaries provides numerous outcrops from which the glacial stratigraphy can be determined (Szabo 1987). However the extent of the units exposed in this valley cannot be traced eastward without the use of subsurface data. This study uses the acquisition and interpretation of subsurface data and the laboratory analyses of surface and subsurface samples to trace late Wisconsinan units into the upland east of the Cuyahoga valley and to improve on the interpretation of their environments of deposition.

MATERIALS AND METHODS

Data used in this study were collected from borehole logs and samples from URS Corporation, roadcuts and additional borings by the authors (Wilson 1991, Kushner 2006), borehole descriptions for new State Route 8 from the Ohio Department of Transportation (ODOT), and water-well logs. URS supplied borehole logs and 147 samples for ten deep borings (Kushner 2006). Eleven grassed road cuts were sampled at one-m intervals using a horizontally driven core sampler, and 13 boreholes were drilled at the base of the cuts and at other locations using a Giddings soil probe. These provided an additional 288 samples (Wilson 1991). Also borehole logs from 27 additional ODOT borings and well logs of 15 water wells were examined to improve correlations among the other subsurface data.

Samples from these various sources were examined, and their Munsell color, texture, consistency, structure, and reaction to dilute

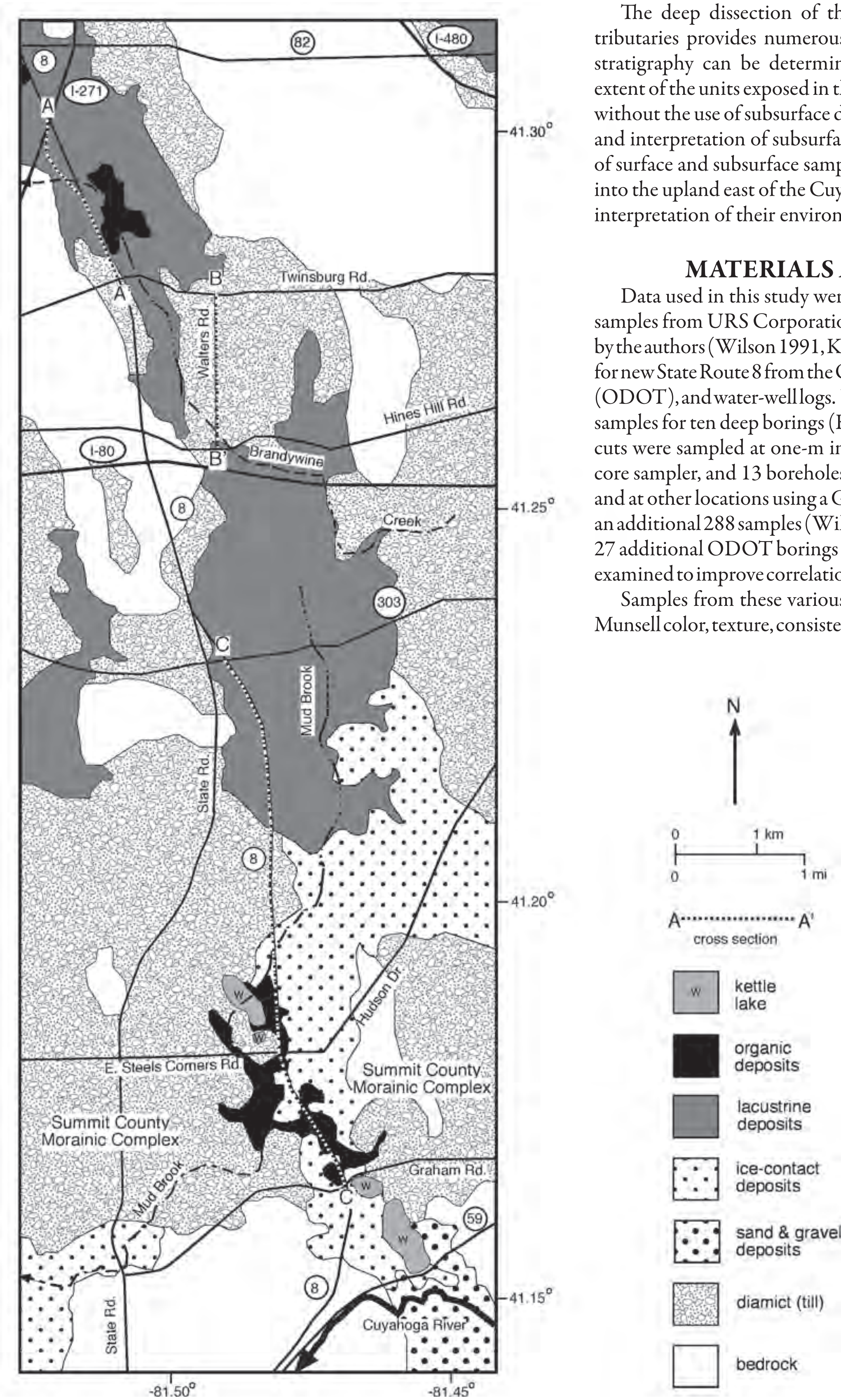


Figure 3. Surficial materials map (derived from Ritchie and Steiger 1974) of the study area. Mud Brook drains the southern part of the areas, and Brandywine Creek drains the northern part.

HCl were noted. In the laboratory, matrix textures (% <2 mm) were determined using a settling and pipetting methods modified from Folk (1974). The sand-silt break in this study is 0.063 mm and the silt-clay break is 4.0 µ. The fine-carbonate content (% <0.074 mm) was determined using a Chittick apparatus (Dreimanis 1962). This size range is the terminal grade for calcite and dolomite and can be related to the provenance of the glacial deposits. The terminal grade is the smallest size to which a rock fragment may be crushed or abraded given the available energy in a glacial environment. Diffraction intensity ratios (DIs) of the clay fractions (<2.0 µ) of some samples (Kushner, 2006) were calculated by measuring the area under the illite peak at 1.0 nm and dividing it by the area under the combined kaolinite and chlorite peak at 0.7 nm (Willman and others 1966, Bruno and others 2006). The lithology of the one to two mm fraction was determined for some samples (Wilson 1991) using a binocular microscope because this fraction is representative of the pebble contents of tills (Anderson 1957). Rock fragment data derived from this procedure were combined to form three categories: clastics, carbonates, and crytallines (Table 2).

Laboratory data, sample descriptions, and borehole logs were used to differentiate among various glacial sediments (Table 2) including those deposited by direct melting of the ice (diamict or till), those deposited by meltwater (silt, sand, and gravel), and those deposited in glacial lakes (clay). Additionally carbonate content was used to assign samples to a particular glacial advance using data summarized in Szabo (2006b). Descriptive statistics were calculated for each lithologic unit (Table 2). North-south geologic cross sections (Fig. 2) showing the age assignments for various groups of units were prepared using the borehole data. Additionally, more detailed cross sections illustrating the geometry of the various lithologic units were drawn for the northern traverse A-A' and the most southernmost two km of traverse C-C' (Fig. 2).

RESULTS

The samples from the borings were grouped into different lithofacies based on grain size and include: interbedded sand, silt, and clay; interbedded silt and clay; silt; sand; sand and gravel; and diamict. We use the term, diamict, for unsorted mixtures of sediment ranging from clay to gravel. Diamicts may have a variety of origins, but in this paper we interpret that they originated in a glacial environment and thus can be referred to as tills when discussing the glacial history of the area. Fine-grained units dominate the subsurface in the northern part of the study area (Kushner 2006), whereas sand and gravel is more common in the southern part (Wilson 1991). Lithofacies were grouped into age units representing different ice advances using stratigraphy from the boreholes and fine-carbonate contents. Similar lithofacies among age units were compared statistically using t tests at $P \leq 0.05$ (Kushner 2006, Wilson 1991) verifying that the separation by fine-carbonate contents was valid.

Cross Section A-A'

Cross section A-A' (Fig. 4) is constructed from data from ten boreholes of which, eight extended into shale. The deep borings terminate in dark gray, fissile shale that correlates with the Mississippian Orangeville Shale Member of the Cuyahoga Formation. Sand and gravel overlies the shale in the center of the cross section (Fig. 4) and has a bipartite nature. The lower part of the sand and gravel contains abundant shale fragments; X-ray diffractograms of the shale show that illite has degraded suggesting that weathered shale was incorporated into the gravels (Kushner 2006). The upper part of the gray gravel has calcite and dolomite contents similar to those of overlying Lavery lithofacies (Table 2). Gray, fine-grained deposits ranging from three to 20 m in thickness overlie the shale and sand and gravel (Fig. 4) and have fine-carbonate contents associated with those of the Lavery Till (Szabo 2006a). Their average DIs (Table 2) represent the erosion and comminution of lower Paleozoic shales by ice (Szabo and Fernandez 1984, Szabo 2006a). Gray, firm, Lavery diamict overlies the fine-grained units, is from two to six m thick, and is discontinuous across the length of the cross section as it rises in elevation southward (Fig. 4). The texture of the Lavery diamict is less clayey than that found just west of the study area in Northampton Township (Ryan 1980), but less silty than that found in southern part of the study area (Wilson 1991). Its total fine carbonate is somewhat less than those values found in other studies in Summit County (Ryan 1980, Angle 1982, Wilson 1991). The average DI of the diamict is 1.5 and is similar to that of the local Mississippian bedrock (Szabo and Fernandez 1984).

Massive to laminated, firm fine-grained lithofacies dominate deposits associated with the Hiram advance and range from two to 17 m thick (Fig. 4). These lithofacies are weathered brown to gray brown near the surface and become grayer with depth. Where at the surface, these units are leached of fine carbonates and their DIs may be as large as 4.0, suggestive of the weathering of chlorite. Within the interbedded silt and clay, calcite contents are significantly larger than dolomite contents (Table 2). In the southernmost borehole (SB101, Fig. 4), 1.5 m of very firm, weakly calcareous diamict overlies gray, calcareous interbedded silt and clay. This is the only occurrence of Hiram Till within the length of the cross section.

Cross Section B-B'

The 1.2-km long cross section B-B' (Fig. 5) is an attempt to trace the sedimentary units farther south by using nine water-well logs from the Ohio Division of Water. This cross section is parallel to the axis of buried valley and uses data from water wells as deep as 32 m along Walters Road (Fig. 2). The superficial descriptions of sediments by various well drillers make it difficult to differentiate among units. We interpret "clay with stones" or "clay with gravel" to be diamicts and "clay with sand" as interbedded units. We are able to separate the sediments recorded in the well logs into deposits of two ages using the occurrence of diamicts in the wells, our interpretation of cross section A-A', and the occurrence of a diamict on the surface (Fig. 3). Hiram-age deposits include the surficial till and fine-grained sediments. Because the Lavery diamict overlies other Lavery-age deposits, we placed the contact between Hiram- and Lavery-age sediments at the top of the second diamict recorded in the well logs.

Cross Section C-C'

Cross section C-C' extends nine km between State Route 303 and Graham Road in Stow where it ends in the Summit County Morainic Complex (Fig. 2). Data for construction of the cross section come from 18 ODOT borings, 12 borings using a Giddings soil probe, 11 measured sections, and six water wells (Fig. 6) collected by Wilson (1991). Her study also incorporates data from four boreholes and three outcrops not along the line of the cross section. This cross section illustrates the distribution of sediments associated with three late Wisconsinan advances, possible older deposits at depth below the southern part of the study area, and the occurrence of resistant sandstone topographic highs (Fig. 6). Kent sediments are relatively continuous across the length of the cross section, whereas Lavery deposits are somewhat less continuous, and Hiram diamicts are relatively discontinuous in comparison (Fig. 6).

There are three lithofacies associated with the Kent advance (Wilson 1991). Friable to firm, silty diamicts are olive brown where oxidized and dark olive gray where unweathered. They contain granules and pebbles and have a slightly delayed reaction to HCl reflective of their small fine-carbonate contents dominated by dolomite (Table 2). Their one to two mm sand fractions contain an average of 13 percent carbonate and are dominated by local sandstone, siltstone, and shale clasts. Silts associated with the Kent advance are massive and firm and weather olive brown. Gray unweathered silts contain an average of 1.1 percent calcite and 4.6 percent dolomite (Table 2); isolated sand layers within the silt contain an average of 21 percent carbonate, which is significantly larger than comparable values for diamicts and sands. Kent sands are generally friable, well sorted, and quartzose. The matrix textures of the Kent sands are silty (Table 2) and contain very little clay. Near-surface sands oxidize brown and are leached of carbonates, whereas deeper sands are olive brown and average about 5.5 percent fine carbonates again dominated by dolomite. The average composition of their sand lithologies is similar to that of the diamict.

Diamict and sand are the only two lithofacies representing the Lavery advance. Very firm, dark brown, oxidized Lavery diamicts have a very strong reaction to HCl and contain secondary carbonates deposited along fractures within the diamicts or as nodules on weathered surfaces. Unoxidized diamicts are dark gray with olive or brown mottling. Fine carbonates consist of nearly equal proportions of calcite and dolomite and average almost nine percent total carbonate. The average one to two mm sand lithology of the diamict is similar to that of the Kent sand (Table 2). Friable, olive gray Lavery sand has an average matrix texture containing less sand and more clay than that of the Kent sand. The fine-carbonate content of the sand averages 11 percent and is larger than that of the diamict. However, its dolomite content is much larger than

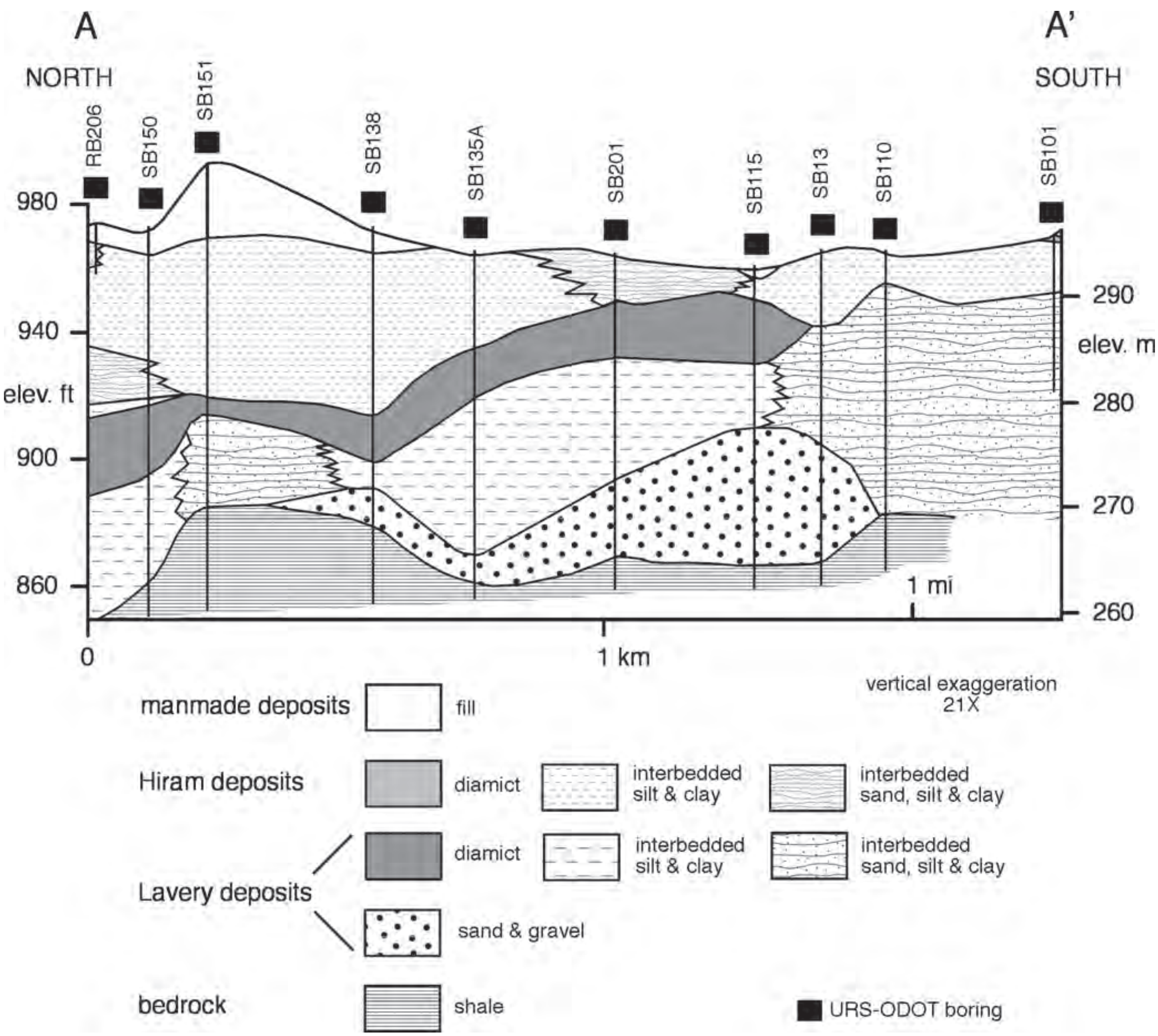


Figure 4. Lithofacies found along cross section A-A' (Fig. 2 and modified from Kushner 2006).

its calcite content (Table 2). The one to two mm sand fractions of this lithofacies contain more crystalline rock fragments than any other lithofacies illustrated in this cross section.

The Hiram advance is represented by yellowish-brown, friable, oxidized diamicts containing granules and small pebbles. These diamicts have a moderate to strong reaction with HCl, but contain

Table 2

Laboratory data for deposits in the areas of cross section A-A' (Kushner 2006) and cross section C-C' (Wilson 1991)

Cross Section Unit	sand* %	silt* %	clay* %	cal %	dol %	tot carb %	DI	carb %	clst %	xtln %
A-A'										
Hiram diamict										
*x***	36	42	22	0.3	0.5	0.8	2.4	n.a	n.a	n.a
s	27	2	45	0.2	0.0	0.2	1.7			
n	2	2	2	2	2	2	2			
Hiram interbedded silt & clay										
x	4	60	36	5.2	4.8	10.0	1.7	n.a	n.a.	n.a.
s	10	23	24	2.6	2.2	3.9	0.6			
n	45	45	45	45	45	45	43			
Hiram interbedded sand. silt & clay										
x	14	60	26	3.7	5.1	8.9	1.8	n.a.	n.a.	n.a.
s	22	29	29	2.3	2.6	4.8	0.7			
n	12	12	12	12	12	12	12			
Lavery diamict										
x	12	52	36	3.6	4.3	7.9	1.5	n.a.	n.a.	n.a.
s	10	21	22	1.7	1.3	2.3	0.3			
n	15	15	15	15	15	15	15			
Lavery interbedded silt & clay										
x	3	56	40	3.1	4.4	7.5	1.6	n.a.	n.a.	n.a.
s	5	24	24	1.0	1.2	1.8	0.3			
n	30	30	30	30	30	30	30			
Lavery interbedded sand. silt & clay										
x	28	44	28	2.5	4.2	6.8	1.9	n.a.	n.a.	n.a.
s	25	21	16	1.2	1.7	2.7	0.7			
n	25	25	25	25	25	25	24			
Lavery sand & gravel										
x	51	40	9	3.3	4.9	8.2	1.8	n.a	n.a	n.a.
s	25	25	10	1.4	1.6	2.6	0.4			
n	18	18	18	18	18	18	18			
C-C'										
Hiram diamict										
x	14	67	19	7.7	4.8	12.6	n.a	16	78	6
s	10	9	7	2.7	2.2	3.9		11	9	4
n	51	51	51	28	28	28		49	49	49
Lavery diamict										
x	14	69	17	4.7	4.2	8.9	n.a.	15	78	7
s	8	8	8	2.1	1.5	3.0		8	8	4
n	129	129	129	90	90	90		129	129	129
Lavery sand										
x	45	46	9	3.9	7.2	11.1	n.a.	14	75	11
s	9	6	6	1.6	0.9	1.5		7	10	3
n	7	7	7	6	6	6		7	7	7
Kent diamict										
x	19	68	13	1.2	3.2	4.4	n.a.	13	79	8
s	10	8	8	0.8	1.1	1.5		6	6	4
n	45	45	45	43	43	43		45	45	45
Kent silt										
x	13	81	6	1.1	4.6	5.7	n.a.	21	74	5
s	7	8	5	0.8	0.8	1.2		6	8	4
n	22	22	22	22	22	22		22	22	22
Kent sand										
x	50	46	4	1.5	4.0	5.5	n.a	15	78	7
s	10	10	5	0.8	1.3	1.8		7	9	4
n	34	34	34	32	32	32		34	34	34

* Percentages of sand, silt and clay are based on matrix weights after gravel was removed
** *x* = mean, s = standard deviation, n = number of samples, cal = calcite, dol = dolomite, total carb = total carbonate, DI = diffraction intensity ratio, carb = carbonates, clst = clastics, xtln = crystallines, n.a. = not analyzed

no secondary carbonates. Fifty-five percent of the Hiram samples contained fine carbonate; samples average 12.6 percent total fine carbonate and in contrast to other sediments found along the cross section, contain significantly more calcite than dolomite (Table 2). The coarse sand lithologies are similar to those of other lithofacies found in the area.

Wilson (1991) included a diagram showing the various lithofacies along cross section C-C'. The general geometry of the deposits can be demonstrated by examining the relationships among lithofacies along the southernmost third of cross section C-C' (Fig. 7) that extends two km northward from Graham Road (Fig. 2). The various sources of subsurface data suggest that there are at least 30 m of sediment overlying shale at the southern end of the cross section: the bulk of this sediment may be pre-Kent in age. Although predominantly sand (Fig. 7), silt, sand and gravel, and diamicts are also present in the subsurface. Kent-aged deposits occur close to the surface and consist of extensive silt and sand overlain by diamict. Multiple Kent diamicts separated by sand form one of the hills (Fig. 7), and Lavery diamicts cap most hilltops. Hiram diamict is only present in the southernmost part of Figure 7 where it overlies Lavery sand and Kent diamict. Cross sections A-A' (Fig. 5) and C-C' (Fig. 7) show that diamict is the last material deposited at the end of each glacial advance.

DISCUSSION

This study illustrates several aspects of glacial deposition over former buried valleys. One of these is that the modern drainage may or may not follow the buried valley. When examining the distribution of buried valleys, it becomes apparent that not all valleys can be combined to form an integrated drainage system (Szabo 2006a). Some ancient valleys are deeply incised into bedrock well below any modern base level. The bottom of the buried valley of the Cuyahoga River near Cleveland is almost at sea level (Szabo 1987), and yet the modern Cuyahoga River enters Lake Erie at 173 m above sea level. Just west of the study area bedrock is about 150 m below the flood plain of the Cuyahoga River (Mangun and others 1981). The bedrock valley floor of Mud Brook in the southwestern part of the study area (Fig. 2) is about 150 m below the surrounding upland and is tied into the ancient valley of the Cuyahoga River.

A tributary to the Mudbrook buried valley flowed northwestward from the southeastern corner of the study area (Fig. 2), but it is evident that glacial meltwater flowed southeastward at State Route 59 (Fig. 3) as suggested by the distribution of sand and gravel confined by bedrock, presence of kettle lakes in the meltwater channel, and thick deposits of sand (Fig. 7). This outwash train continues southward through Akron, eventually joining the Tuscarawas River (Szabo 2006a). The modern course of Mud Brook has returned to follow its ancestral drainage to the southwest (Fig. 3) having formed as a consequence of the post-glacial topography and headward erosion of a post-glacial tributary following the buried valley of Mud Brook from the Cuyahoga Valley.

Another important aspect of this buried valley is that it illustrates the occurrence of similar depositional processes for each ice advance. There may have been an extensive ice-free period between the

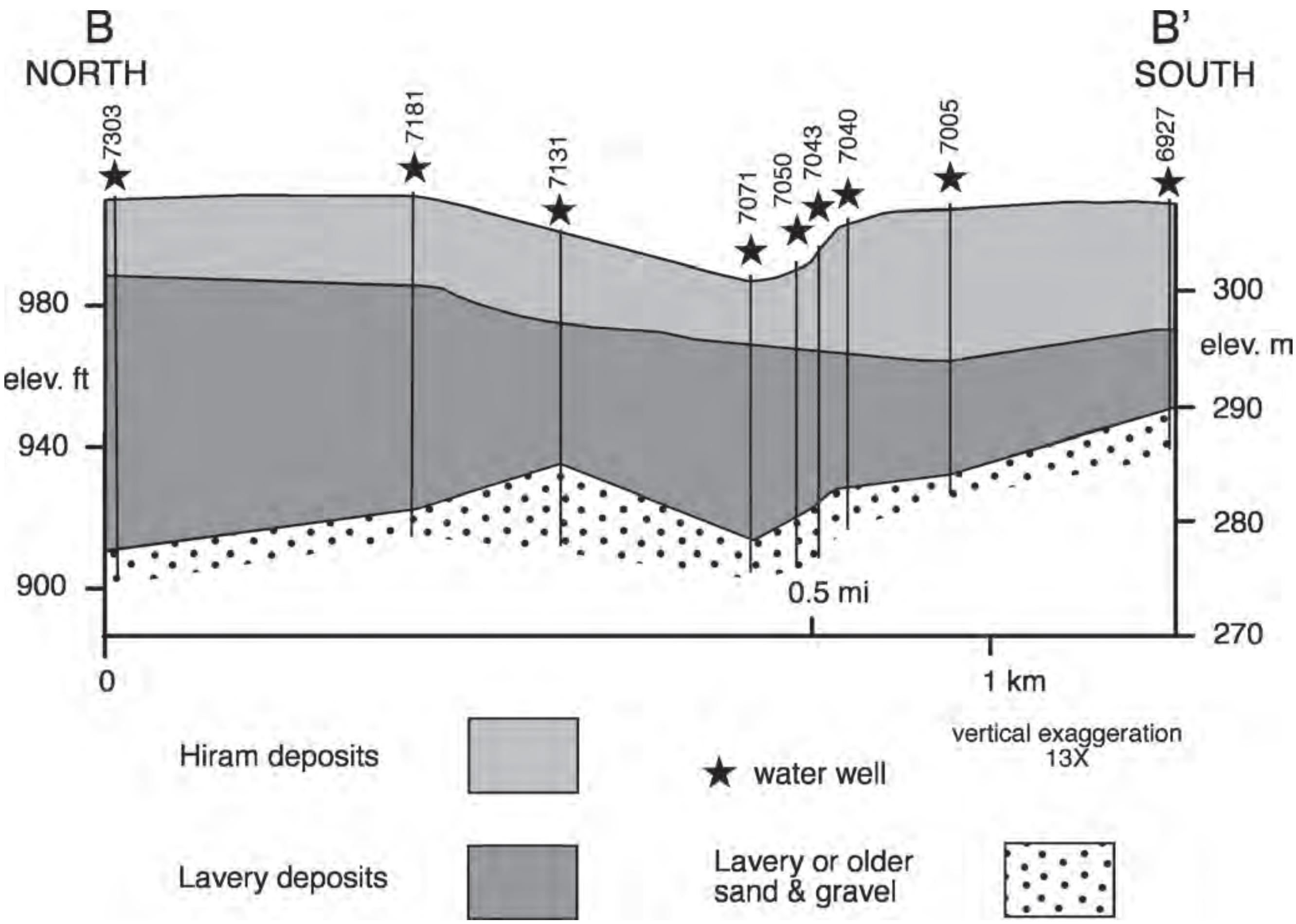


FIGURE 5. Cross section B-B' (modified from Kushner 2006) shows the distribution of Hiram- and Lavery-aged glacial deposits as constructed from water-well logs along Walters Road (Fig. 2).

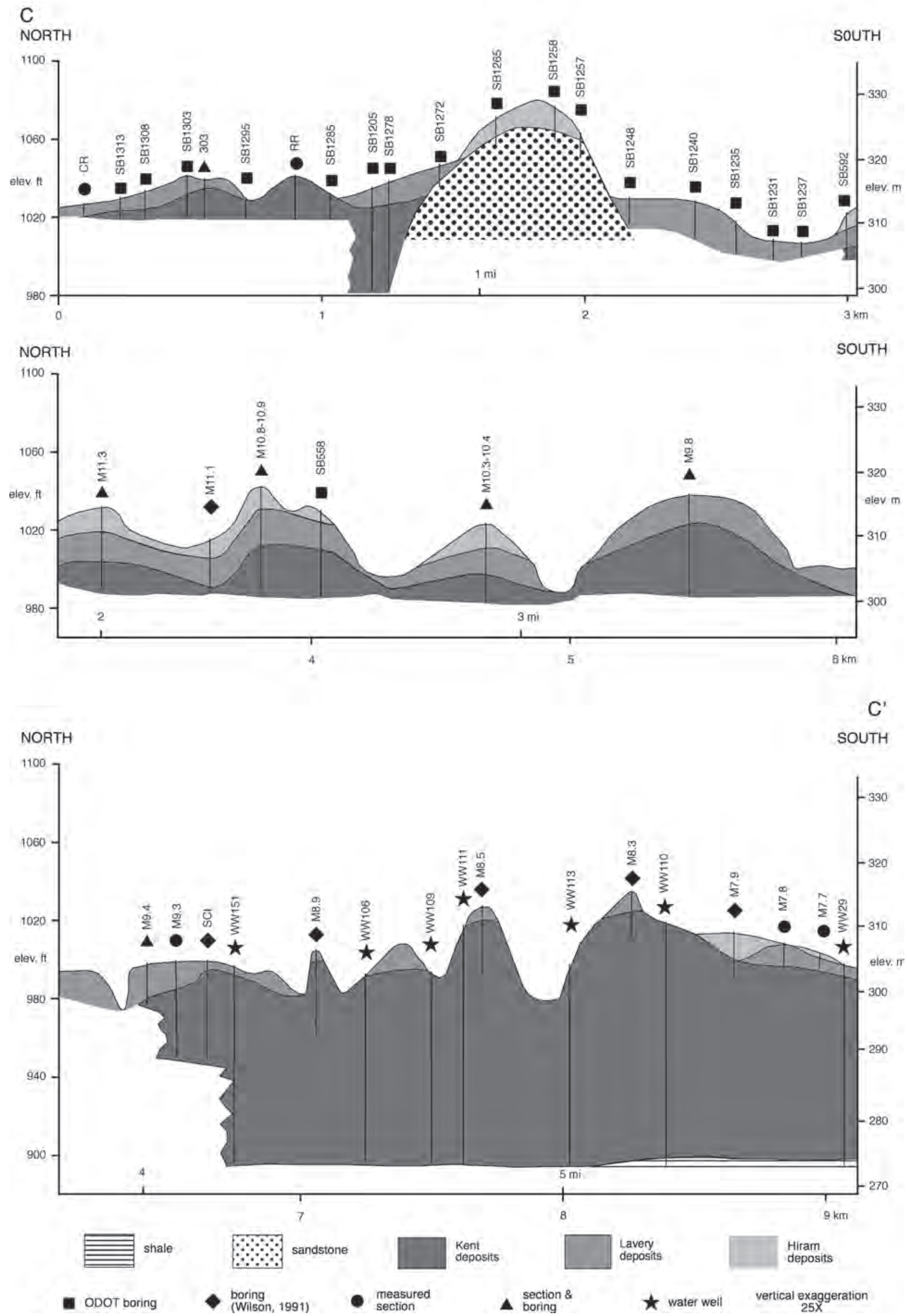


Figure 6. Cross section C-C' (Fig. 2) showing the distribution of Wisconsinan and possible older deposits (modified from Wilson 1991) is broken into thirds. Northern third is at the top and southern third is at the bottom of the figure.

end of the Illinoian glaciations that deposited the Mogadore and Northampton tills (Table 1). The sequence of thick sediments well below the Kent-aged deposits in the southern part of the study area may be Illinoian in age (Fig. 7). The presence of intensely weathered shale in the lower part of the basal sand and gravel (Fig. 4) suggests a period of weathering and fluvial erosion during the Sangamonian Interglaciation and before the late Wisconsinan advances (Kushner 2006).

Kent ice advanced southward out of the Erie basin about 23,000 radiocarbon years ago (Szabo 2006a). Wilson (1991) suspected that the Kent ice of the Grand River lobe may have flowed into the study area from the northeast. Her hypothesis is based on the absence of Kent deposits west of the study area (Ryan 1980) and only as far south as Garfield Heights north of the study area (Szabo 2006a). Thus the study area may have been an ice-marginal area accounting for the majority of silty water-laid deposits (Fig. 7) that were reworked into Kent-age deposits. Topographically the hills in the ice-contact area (Fig. 3) appear to be kames, but their internal structure reflects a slightly different mode of origin. The distribution of sediments in the area and the generally flat-topped nature of the kames not apparent on the vertically exaggerated cross sections suggest that the ice-contact area may have originated as a kame plateau (Brodzikowski and Van Loon 1987) consisting of small lakes and meltwater stream channels initially forming on top of the ice and let down on the landscape as the ice melted. The presence of Kent diamicts in the upper parts of the kames may imply local readvance during a prolonged period of stagnation of Kent ice on the Allegheny Plateau (Szabo 2006a).

After retreat of the Kent ice margin into Canada during the Erie Interstade about 16,500 radiocarbon years ago (Szabo 2006a),

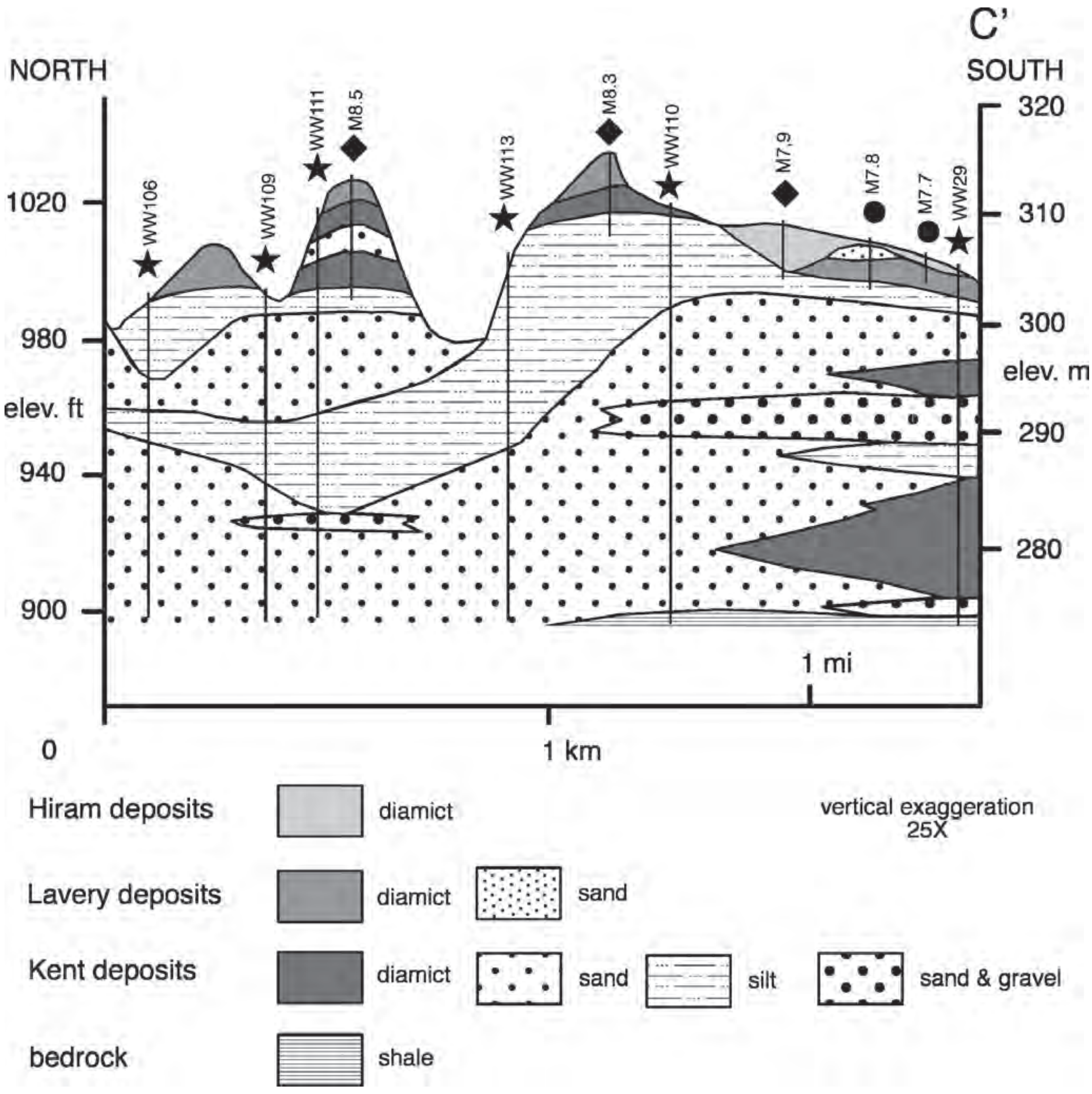


FIGURE 7. Lithofacies found along the southern third of cross section C-C' (Fig. 6). Note the abundance of water-laid sediments and how late Wisconsinan diamicts cap the hilltops.

an ancestor of Mud Brook may have continued to drain the area. The northern cross section, A-A' (Fig. 4) may suggest this or proglacial meltwater from the first advance after the interstade may have removed any Kent-aged deposits in the area. Heavy-mineral assemblages in tills deposited just after the Erie Interstade suggest a major change in ice flow from north-south across the Erie Basin to northeast-southwest down the axis of modern Lake Erie (Hofer and Szabo 1993). As Lavery ice from the Cuyahoga lobe (Szabo 2006a) advanced southward through the study area, proglacial meltwater may have removed any older Kent deposits depositing abundant fine-grained sediments and sand and gravel (Fig. 4). Slight increases in DIs and mottling of laminated clays suggest a possible inwashing of weathered sediments from local topographic highs. Lavery ice advanced over its own proglacial sediments until it reached the Summit County Morainic complex north of the modern Cuyahoga River. There it augmented the bulk of the original moraine and kame plateau by superposing a layer of diamict over the older deposits. The maximum extent of Lavery ice appears to have been just south of Graham Road (Fig. 3).

Following a retreat of Lavery ice northward into the Erie basin, Hiram ice flowed southward depositing a similar depositional sequence as that deposited by the Lavery ice (Fig. 4). Again fine-grained sediments were deposited proglacially and overridden by Hiram ice that laid down a layer of diamict as it advanced to the morainic complex. The relief of the area was again increased by the addition of another layer of superposed diamict (Fig. 7). Meltwater may have been directed along the margin of the ice at this time to form the middle Cuyahoga River that drained through a sag in what is now downtown Akron into the Tuscarawas River. It is not known if the ice masses that eventually formed the kettle lakes at the margin of the morainic complex broke off from Lavery or Hiram ice. However, it can be deduced by the lateral distribution and thickness of sediments that meltwater continued to flow around the detached ice blocks.

Because stratigraphic data were only collected in a north-south direction and vertically, the lateral variation in sediments in the east-west direction is lacking. Some information can be deduced from the materials map (Fig. 3) and field observations. These show that following retreat of the Hiram ice, possibly meltwater and eventually local runoff was ponded in low areas between bedrock highs adjacent to the valley and morainal deposits within the valley. Lacustrine deposits (Fig. 3) imply that several large lakes formed in the valley of Mud Brook and probably contained water until naturally drained by integration of the Mud Brook drainage network or artificially by early settlers in the area. These lake beds are not perfectly flat and contain low knolls of diamict suggestive of drowned ground moraine.

This study has illustrated the late glacial stratigraphy of buried valley sediments in the direction of ice flow. It has shown the similarity of processes of advancing ice during late Wisconsinan glaciations and the superposition of glacial sediments to form the modern landscape. This study also illustrates the importance of using combined data from a variety of sources to better understand the glacial stratigraphy of an upland area.

Acknowledgments. The authors thank the Ohio Department of Transportation for access to borehole logs and permission to sample roadcuts and drill additional holes along State Route 8 between Graham Road and State Route 303. We also thank Thomas George and URS Corporation for providing borehole logs and samples for State Route 8 between I-271 and Twinsburg Road. The comments of five anonymous reviewers are greatly appreciated.

LITERATURE CITED

Allahiari M. 1983. Morphometric analysis of the Mud Brook basin of northeastern Summit County, Ohio [Unpubl MS thesis]. Akron (OH): Univ. of Akron. 85 p.

Anderson RC. 1957. Pebble and sand lithology of the major Wisconsin glacial lobes of the Central Lowland. Geological Society of America Bulletin 68:1415-50.

Angle MP. 1982. Quaternary stratigraphy of part of Richfield Township, Summit County, Ohio [Unpubl MS thesis]. Akron (OH): Univ. of Akron. 155 p.

Brodzikowski K, Van Loon AJ. 1987. A systematic classification of glacial and periglacial environments, facies and deposits. Earth Sci. Reviews 24:297-381.

Bruno, PW, Szabo JP, Foos A. 2006. Mineralogy of weathered Wisconsinan till along a fracture in the root zone. Ohio J Sci 106:17-21.

Dreimanis A. 1962. Quantitative gasometric determination of calcite and dolomite by using a Chittick apparatus. J. Sedimentary Petrology 32:520-9.

Folk RL. 1974. Petrology of sedimentary rocks. Austin (TX): Hemphill Publ. Co. 182 p.

Gardner SP. 1981. A seismic investigation of a buried valley near Cuyahoga Falls, Ohio [Unpubl MS thesis]. Akron (OH): Univ. of Akron. 169 p.

Hofer JW, Szabo JP. 1993. Port Bruce ice-flow directions based on heavy-mineral assemblages in tills from the south shore of Lake Erie in Ohio. Canadian J. Earth Sciences 30:1236-41.

Kushner VA. 2006. Stratigraphic correlation of late Pleistocene sediments of a buried valley in Northfield Center Township, Summit County, Ohio [Unpubl MS thesis]. Akron (OH): Univ. of Akron. 105 p.

Mangun M, Kunze AWG, Szabo JP. 1981. Seismic refraction study of a buried valley near Peninsula, Summit County. Ohio J Sci 81:69-73.

Pavey RR, Goldthwait RP, Brockman CS. Hull DN, Swinford EM, Van Horn RG. 1999. Quaternary geology of Ohio. Ohio Div. of Geological Survey Map 2 (scale 1: 500,000).

Ohio Drilling Company. 1971. Groundwater potential of northeast Ohio. Report for the Ohio Department of Natural Resources. Available from the Ohio Div. of Water, Columbus, OH. 360 p.

Olver R. 1981. Resistivity investigation of a buried valley in Summit County, Ohio [Unpubl MS thesis]. Akron (OH): Univ. of Akron. 128 p.

Ritchie A, Steiger JR. 1974. Soil Survey of Summit County, Ohio. U.S. Dept. of Agriculture. 117 p.

Ryan DE. 1980. Quaternary stratigraphy of the lower Mud Brook basin, Northampton Township, Summit County, Ohio [Unpubl MS thesis]. Akron (OH): Univ. of Akron. 140 p.

Schmidt JJ. 1979. Ground-water resources of Summit County. Ohio Div. of Water Map.

Smith RD, White GW. 1953. Ground-water resources of Summit County, Ohio. Ohio Div. of Water Bulletin 27, 130 p.

Szabo JP. 1987. Wisconsinan stratigraphy of the Cuyahoga Valley in the Erie basin, northeastern Ohio. Canadian J. Earth Sciences 24:279-90.

Szabo JP. 2006a. Quaternary geology of the interlobate area between the Cuyahoga and Grand River lobes, northeastern Ohio. Ohio Div. of Geological Survey Guidebook 20. 52 p.

Szabo JP. 2006b. Textural and mineralogical characteristics of tills of northeastern and north-central Ohio. Ohio J Sci 106:9-16.

Szabo JP, Fernandez RL. 1984. Clay mineralogy of Wisconsinan tills of the Cuyahoga Valley National Recreation Area, northeastern Ohio. Ohio J Sci 84:205-14.

Szabo JP, Ryan DE. 1980. Quaternary stratigraphy of the lower Mud Brook basin, Northampton Township, Summit County, Ohio. Ohio J Sci 80:38-44.

White GW. 1982. Pleistocene geology of northeastern Ohio. Ohio Div. of Geological Survey Bulletin 68. 75 p.

White GW. 1984. Glacial geology of Summit County, Ohio. Ohio Div. of Geological Survey Report of Investigations 123. 25 p.

Willman HB, Glass HD, Frye JC. 1966. Mineralogy of glacial tills and their weathering profiles in Illinois, Part II. Weathering profiles. Urbana (IL): Illinois State Geological Survey Circular 400. 76 p.

Wilson, CGH. 1991. The origin and relative age of kames in Stow and Hudson townships, Summit County, Ohio [Unpubl MS thesis]. Akron (OH): Univ. of Akron. 113 p.